METHODS AND APPARATUSES FOR LAUNCHING AIRBORNE DEVICES ALONG FLEXIBLE ELONGATED MEMBERS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to pending U.S. Provisional Application No. 60/459,900, filed April 1, 2003 and incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present disclosure describes methods and apparatuses for launching airborne devices (e.g., unmanned aircraft) along flexible, elongated members (e.g., cables).

BACKGROUND

[0003] Unmanned aircraft or air vehicles (UAVs) provide enhanced and economical access to areas where manned flight operations are unacceptably costly and/or dangerous. For example, unmanned aircraft outfitted with remotely controlled cameras can perform a wide variety of surveillance missions, including spotting schools of fish for the fisheries industry, monitoring weather conditions, providing border patrols for national governments, and providing military surveillance before, during and/or after military operations.

[0004] Existing unmanned aircraft systems suffer from a variety of drawbacks. For example, existing unmanned aircraft systems (which can include the aircraft itself along with launch devices, recovery devices, and storage methods) typically require substantial space. Accordingly, these systems can be difficult to install and operate in cramped quarters, such as the deck of a small fishing boat, land vehicle or other craft. Lack of portability, inefficient use of transport space, and

less than rapid deployment are also drawbacks with some systems. Another drawback with some existing unmanned aircraft is that, due to small size and low weight, they can be subjected to larger acceleration, deceleration, and other forces than can larger, manned air vehicles. Accordingly, small UAVs may be prone to damage, particularly during recovery and launch operations in hostile environments, such as a heaving ship deck.

SUMMARY

[0005] The present invention is directed generally toward methods and apparatuses for launching an airborne device, including an unmanned aircraft. An apparatus in accordance with one aspect of the invention includes a support and at least one flexible, elongated member having a first portion coupled to the support at a first attachment site, and a second portion coupled at a second attachment site that is spaced apart from the first attachment site. The at least one flexible, elongated member can be tensioned and aligned along a launch path. A launch cradle can be carried by the at least one flexible, elongated member and can be movable relative to the at least one flexible, elongated member along the launch path. The launch cradle can include a carrier positioned to support the airborne device as the cradle moves along the launch path.

[0006] In further aspects of the invention, the carrier can include a gripper positioned to releasably grip a wing of the airborne device. The gripper can disengage from the wing as the cradle decelerates. In another aspect of the invention, the support can be articulated and movable between a first position and a second position. The apparatus can further comprise a coupling connected between the support and the launch cradle to move the launch cradle along the launch path as the support moves between the first and second positions.

[0007] A method in accordance with another aspect of the invention includes releasably carrying an airborne device with a cradle prior to launch, and accelerating the cradle along at least one flexible, elongated member aligned with a launch path. The method can further include decelerating the cradle and releasing the airborne device from the cradle for flight. In further aspects of the

invention, the method can further include deploying the at least one flexible, elongated member at an inclined angle, tensioning the at least one flexible, elongated member, and suspending the cradle from the at least one flexible, elongated member. The method can still further include releasing tension in the at least one flexible, elongated member and stowing the at least one flexible, elongated member after the airborne device is released.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 illustrates a system having a structure with cables or other flexible, elongated members forming a launch guide along which an unmanned aircraft and its launch cradle are accelerated in accordance with an embodiment of the invention.

[0009] Figure 2 illustrates a system having a single elongated guide member and two tow lines in accordance with another embodiment of the invention.

[0010] Figures 3A and 3B illustrate methods and systems for applying external forces to accelerate an unmanned aircraft and its launch cradle in accordance with further embodiments of the invention.

[0011] Figure 4 illustrates an apparatus including part of a launch cradle configured to grip wing surfaces or extensions of the body of an aircraft or other airborne device during launch acceleration, in accordance with an embodiment of the invention.

[0012] Figure 5 illustrates an apparatus for launching an aircraft with a single tow line, in accordance with another embodiment of the invention.

DETAILED DESCRIPTION

[0013] The present disclosure describes methods and apparatuses for launching unmanned aircraft or other projectiles. Many specific details of certain embodiments of the invention are set forth in the following description and in Figures 1-5 to provide a thorough understanding of these embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, and that the invention may be practiced without several

of the details described below. For example, many of the aspects described below in the context of launching unmanned aircraft may be applicable as well to other self-propelled and/or projectile airborne devices.

[0014] Figure 1 illustrates a launch system 100 having a support 110 (e.g., a boom, derrick or tower) from which one or more flexible, elongated members 120 extend in accordance with an embodiment of the invention. The support 110 can include a first portion 110a pivotably and collapsibly coupled to a second portion 110b. The second portion 110b can include a transverse element 110c, and the support 110 can be stabilized with one or more support cables 160. The transverse element 110c can provide an attachment point 111 for a portion of each flexible, elongated member 120. The elongated members 120 can include cables, ropes or other devices. An opposing portion of each elongated member 120 can be secured to the ground, or to a fixed platform or surface 130, or to another tower or structure at a securement point 131. When the elongated members 120 are placed under tension, they can form an inclined launch track or guide 121 that guides the motion of a launch carriage or cradle 140.

[0015] The cradle 140 can include attachment devices 141 that contact the elongated members 120 and support the cradle 140 relative to the elongated members 120. The attachment devices 141 can include rollers, slides, or other mechanisms that allow the cradle 140 to move in a low-friction manner along the elongated members 120. An unmanned aircraft 150 or other projectile can be releasably carried by the launch cradle 140. As used herein, the term cradle refers to any structure that can carry the unmanned aircraft (or other airborne device) during launch. The system 100 can further include an energy system 180 (e.g., a winch) coupled to the cradle with a towline 170 or other coupling. Accordingly, the energy system 180 can accelerate the cradle 140 at least until the cradle 140 achieves the launch velocity of the aircraft 150, while the cradle 140 is guided by the elongated members 120.

[0016] The launch cradle 140 and the aircraft 150 can be accelerated along the elongated members 120, beginning at or near the securement point 131 and ending at or near the attachment point 111 toward the upper end of the support

110. The cradle 140 can be rapidly decelerated by a braking mechanism as it approaches the attachment point 111, so that the aircraft 150 is released from the cradle 140 and continues into flight.

[0017] Figure 2 illustrates a launch system 200 having a single flexible elongated member 220 (e.g., a cable) and two tensioned towlines 270 to accelerate the aircraft 150, in accordance with another embodiment of the invention. In one aspect of this embodiment, the launch system 200 can include a support 210 to which one portion (e.g., one end) of the elongated member 220 is secured. The opposing portion (e.g., the opposing end) of the elongated member 220 can be secured to the ground or to a fixed platform or surface 130 (Figure 1) or to another tower or structure. Tension can be applied to the elongated member 220 to form a launch track or guide 221 for a cradle 240 that is supported for movement relative to the elongated member 220 via an attachment device 241. The attachment device 241 can include a set of rollers, slides, or other mechanisms that allow the cradle 240 to move along the elongated member 220, in a manner generally similar to that described above. The aircraft 150 or other projectile can be releasably carried by the launch cradle 240. The towlines 270 can be attached between the cradle 240 and an energy source to accelerate the cradle 240 and the aircraft 150. One or more support cables 260 can stabilize the support 210. In another embodiment, the two towlines 270 shown in Figure 2 can be replaced with a single towline 270, as described in greater detail below with reference to Figure 5. In still further embodiments, the launch system 200 can have other arrangements.

[0018] Figure 3A illustrates an energy system 380 configured to provide energy for accelerating the cradles and the aircraft 150 described above, in accordance with an embodiment of the invention. In one aspect of this embodiment, the energy system 380 can include an articulated support 310 that includes one or more joints 112. The support 310 can also carry one or more elongated members and a launch cradle (e.g., generally similar to the arrangement shown in Figure 1 or Figure 2), which are not shown in Figure 3A for purposes of clarity. A coupling 370 (e.g., a towline) can be suspended from the support 310 by a series of pulleys

372 so as to form a block and tackle arrangement 371. The support 310 is then placed in a bent position, as shown in Figure 3A. When the structure 310 straightens (as indicated by arrows "S"), it produces tension in the coupling 370, and accelerates any mass 382 attached to the coupling 370. The mass 382 can include a launch cradle and unmanned aircraft, e.g., generally similar to those described above with reference to Figures 1 and 2.

[0019] An energy source 381 can be coupled to the support 310 to straighten the support 310. The energy source 381 can include a potential energy source, e.g., one or more suspended weights, an elastic cord or other spring, a pneumatic cylinder, and/or a flywheel. The potential energy source can be powered by any of several mechanisms that convert kinetic energy into potential energy, for example, to restore energy to the potential energy source prior to the next launch cycle. In other embodiments, the energy system 380 can include other arrangements to accelerate the mass 382 (e.g., the cradle and aircraft) at the end of the coupling 370. In still other embodiments, the support 310 can have other arrangements. For example, the support 310 can be extended in a "scissors" fashion.

[0020] In another embodiment, shown in Figure 3B, the support 310 can be fixed, and can include one or more pulleys 373 that translate motion from the energy system 380 into the coupling 370. The energy system 380 in this embodiment can include any of the energy sources 381 described above, and can act through a spool 374 to reel in the coupling 370, either directly or through a mechanism (e.g., a block and tackle) that magnifies the length over which the acceleration takes place.

[0021] Figure 4 illustrates a launch system 400 that includes a launch cradle 440 for carrying the aircraft 150 (a portion of which is shown in Figure 4) in accordance with an embodiment of the invention. The launch cradle 440 can include a central body 442, one or more sets of rollers, slides or other low-friction attachment devices 441 that attach the cradle 440 to the elongated member(s) 120, and a carrier 449 that supports the aircraft 150. The carrier 449 can include a gripper 443 that, in one embodiment, can releasably secure the wings 151 of the aircraft

150 during launch acceleration. In other embodiments, the gripper 443 can secure the fuselage or other portions of the aircraft 150. In an embodiment shown in Figure 4, the gripper 143 can include two pairs of gripping arms 445, one for each wing 151 (one pair of gripping arms 445 is shown in Figure 4 as including a first or upper arm 445a and a second or lower arm 445b). The upper and lower arms 445a, 445b can be coupled at a pivot joint 444 so that at least one arm 445 is rotatable relative to the other. Accordingly, the pivot joint 444 can include a first portion coupled to the upper gripping arm 445a and a second portion coupled to the lower gripping arm 445b.

[0022] A counterweight 446 can be coupled to the upper gripping arm 445a or the first portion of the pivot joint 444. As the cradle 140 accelerates, the inertia of the counterweight 446 causes the upper gripping arm 445a to rotate around a pivot axis 447 (as indicated by arrow A) to the position shown in solid lines in Figure 4. Accordingly, the upper arm 445b can clamp the wing 151 against the lower arm 445a. When the launch cradle 440 is decelerated, the inertia of the counterweight 446 rotates the counterweight 446 clockwise about the pivot axis 447 (as indicated by arrow B) to open the upper gripping arm 445a (as shown in phantom lines). This action releases the wing 151 and the unmanned aircraft 150. Optionally, the lower gripping arm 445b can also open (as shown in phantom lines). In either embodiment, the gripper 443 is changeable from a first configuration (in which the gripper 443 is engaged with the wing 151) to a second configuration (in which the gripper 443 is disengaged from the wing 151).

[0023] The gripping arms 445 can include compliant, resilient and/or cushioning surfaces 448 to reduce the potential for damage to the wings 151 or other surfaces of the aircraft 150 contacted by the gripping arms 445. In other embodiments, the gripper 443 can include arm surfaces in addition to or in lieu of those shown in Figure 4. In any of these embodiments, the gripper 443 can securely grip the aircraft 150 as it accelerates so as to resist ambient windloads, gravity, thrust generated by the aircraft's propulsion system, and other external transitory loads. In still further embodiments, devices other than the counterweight 446 and the pivot mechanism illustrated in Figure 4 can be used to

selectively close and open the gripper 443. In yet further embodiments, tripping mechanisms, including spring-loaded pins, release devices, magnetic switches, or other devices can be used to trigger the release of the gripper 443 as it passes a specified point along the launch path.

[0024] The system 400 can also be configured to absorb the kinetic energy of the cradle 440 as the cradle 440 decelerates. For example, at least a portion of the support 110 can be flexible and resilient. In a particular embodiment shown in Figure 4, the support 110 can include a transverse element 110a and a flexible, resilient attachment portion 110d to which the elongated member 120 is attached. As the cradle 440 decelerates, the attachment portion 110d can deform (e.g., by flexing or bending) to absorb the kinetic energy of the cradle 440. In other embodiments, the system 400 can include other arrangements for absorbing the kinetic energy of the cradle 440, without damaging the cradle 440, the elongated member 120 along which the cradle 440 travels, or the support 110 to which the elongated member 120 is attached.

[0025] Figure 5 illustrates a launch system 500 configured in accordance with another embodiment of the invention. In one aspect of this embodiment, the system 500 can include a boom, derrick, tower or other elongated support structure 510, which supports a tensioned cable or other flexible, elongated member 520. A cradle 540 can be suspended from the elongated member 520 and can carry the aircraft 150 with a gripper 543. In one embodiment, the gripper 543 can operate in a manner generally similar to that of the gripper 443 described above, and in other embodiments, the gripper 543 can operate in other manners.

[0026] In one aspect of an embodiment shown in Figure 5, the gripper 543 is carried by two arms 542, each of which extends outwardly from the cradle 540. The arms 542 can engage a brake 560 positioned toward the end of the elongated member 520 to decelerate the cradle 540 as the aircraft 150 is launched. In a further aspect of this embodiment, the brake 560 and/or the arms 542 are flexible or movable to cushion the effect of the impact between these two components as the cradle 540 decelerates. In other embodiments, the cradle 540 can be decelerated with other mechanisms. Still another feature of an embodiment

shown in Figure 5 is that the cradle 540 can be attached to a single towline 570. The towline 570 can be accelerated with any of the energy systems described above.

[0027] One feature of embodiments of the launch systems described above is that they can include one or more flexible, elongated members (e.g., cables or ropes) that form a launch guide. An advantage of this feature is that the launch system can be easily and quickly activated by deploying the elongated member(s) and deactivated by stowing the elongated member(s). Accordingly, the system can be readily installed and operated in cramped quarters, including the deck of a small boat or other vehicle.

[0028] Another feature of embodiments of the launch systems described above is that the flexible, elongated member(s) can be relatively long, without requiring a bulky, heavy, or otherwise cumbersome track. An advantage of this arrangement is that the long acceleration course can reduce the peak loads applied to the aircraft during launch. Another advantage of this arrangement is that its streamlined, simple construction can further increase the ease with which the system can be installed and operated in cramped quarters.

[0029] Still another feature of embodiments of the systems described above is that the support can be articulated and operatively coupled to the launch cradle it carries. One advantage of this arrangement is that the support can not only carry the cradle, but can also accelerate the cradle, potentially reducing the weight and volume occupied by the portion of the system required to accelerate the cradle. Another advantage of this feature is that the support can be easily collapsed, further reducing the volume occupied by the support when it is not in use.

[0030] Yet another feature of embodiments of the systems described above is that they can grip the wings of the aircraft (e.g., the wing upper and lower surfaces) during acceleration, release the wings during launch, and at least reduce the likelihood for damage to the wings throughout both processes. A further feature is that the system can automatically release the aircraft when the cradle begins to decelerate. An advantage of these features is that the aircraft can be efficiently

and safely supported during launch and can be easily released during launch without having portions of the aircraft strike the launch structure.

[0031] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. For example, the systems described above can be used to launch aircraft having arrangements different than those described above. In other embodiments, these systems can handle projectiles or other airborne devices. Aspects of the invention described in the context of particular embodiments can be combined or eliminated in other embodiments. For example, the launch guides (e.g., those illustrated in Figure 1, 2 or 5), one or more of the energy sources (e.g., those illustrated in Figures 3A-3B), and one or more of the grippers employing an automatic release mechanism (e.g., those illustrated in Figures 4 and 5) can be used together in one system. In other embodiments, they can be used in pairs or separately. In still further embodiments, the launch cradles described above can support the airborne device in manners other than those shown in the Figures. Accordingly, the invention is not limited, except as by the appended claims.